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EFFECTS OF GAMMAS AND NEUTRONS ON LEAD SELENIDE DETECTORS

Peter A. Borgo, 1Lt, USAF

TECHNICAL REPORT NO. AFWL-TR-66-62
September 1966

AIR FORCE WEAPONS LABORATORY
Research and Technology Division
Air Force Systems Command
Kirtland Air Force Base
New Mexico

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FOREWORD

This research was performed under Program Element 6.24.05.06.4, Project 5791, Task 579122. Inclusive dates of research were February 1966 to May 1966. The report was submitted 17 July 1966 by the AFWL Project Officer, Lt Peter A. Borgo (WLDE).

This report has been reviewed and is approved.

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ABSTRACT

Objectives of this program were to determine the effect of neutrons from a near nuclear burst on infrared systems. A cooled lead selenide detector (-80°C) was radiated, using the fast burst reactor at White Sands Missile Range to provide a neutron flux of approximately 10^{13} neutrons/cm^2. A series of six bursts was conducted over a 2-day period. Results show a large output from the detector at burst time. The recovery time from this pulse is on the order of from 3 to 5 milliseconds. This is approximately 100 times the burst pulse width. There is some indication that a period of approximately 100-150 milliseconds is required before postburst operation of the detector is exactly equivalent to the preburst operation. Recalibration of the detector after the burst series indicated a very small loss in sensitivity. In general, the postburst noise and resistance figures were slightly higher than the preburst values.

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SECTION I

INTRODUCTION

Interest has been generated in determining the effect neutrons from a near nuclear burst would have on infrared detection systems. The program described in this paper is a result of this interest.

The Fast Burst Reactor (FBR) at White Sands Missile Range was used to provide a neutron flux that simulated a near nuclear burst situation. A van parked outside of the reactor cell was used as an instrumentation laboratory to record the test data.

General operation characteristics of the FBR along with the van data gathering procedures are presented in the following sections. A compilation and discussion of results is also presented.

SECTION II

TEST PROCEDURES

1. Nuclear Effects Laboratory Facility

The Nuclear Effects Laboratory (NEL) is located in south central New Mexico about 3 miles southeast of the central facilities of the White Sands Missile Range. NEL is a unit within the Electro-Mechanical Laboratories of the White Sands Army Missile Test and Evaluation Directorate*.

The NEL consists of two sections. One section is a laboratory building housing a gamma LINAC, a Pulsed Neutron Generator, and various supporting activities such as a health physics department, radioactive storage areas, etc. The other section is the Fast Burst Reactor Facility.

The FBR is housed in a 38-foot deep pit. The reactor is raised into a 50-foot square concrete chamber for firing.

Any experiments to be radiated are placed in this chamber at various distances from the reactor core. Provisions are made for cabling through conduits to allow self-contained instrumentation vans to be used for data acquisition from a parking area outside of the cell.

The FBR is an unreflected and unmoderated critical assembly that consists of a right circular cylinder and four controlling components fabricated from Uranium Molybdenum alloy (U-10 w/o Mo Fuel).

The alloying of uranium with molybdenum improves the dimensional stability by retaining a crystalline structure (gamma phase) of greater stability and strength. The FBR is capable of producing both high yield, short duration neutron pulses and steady state operations up to 10 kilowatts of power. The pulse mode was used throughout this program. Burst performance characteristics are presented in table I.

---

*Nuclear Effects Laboratory Technical Report on Radiation Facilities (dated December 1963) prepared by William M. Cole.

Table I

CALCULATED PERFORMANCE CHARACTERISTICS OF THE WSMR FBR (PULSE MODE)

Burst Yield, fissions	2×10^{17}
Integrated neutron flux, 1 inch from reactor surface (neutrons/cm^2)	$> 2 \times 10^{14}$
Peak instantaneous gamma ray dose (rads/sec)	3×10^8
Burst half-width (μsec)	50
Average Temperature rise (°C)	250-350

The FBR provides an excellent source of neutrons and gamma radiation for the simulation of nuclear weapon environments. Figure 1 is a comparison of the watt's fission spectrum, fission weapon spectrum, and the FBR spectrum. The ratio of neutron dose to gamma dose is approximately 10 to 1.

2. Instrumented Van System

a. Detector Configuration

The detector was mounted in a small glass dewar. A Copper-Constantum thermocouple was also installed in the dewar to monitor detector cooling. This entire unit was housed in an aluminum box with a small hole for the detector to "look" out of. A 6-volt incandescent light was mounted to the box directly in front of the small hole. The light was pulsed on and off before, during, and after each burst. Provisions were made to record the thermocouple and detector outputs and the light pulse. The detector used in this program was lead selenide cooled by liquid Freon 13 to approximately -80°C. The detector was biased with 26.5 vdc through a 1 megohm load. The detector resistance varied from 350 kil-ohms at ambient temperature to approximately 5 meghoms when cooled. The measured noise voltage and D* before the test series, were 50 μvolts rms and 4.5×10^9 cm $cps^{1/2}$ $watt^{-1}$ at -80°C, 780 cps respectively.

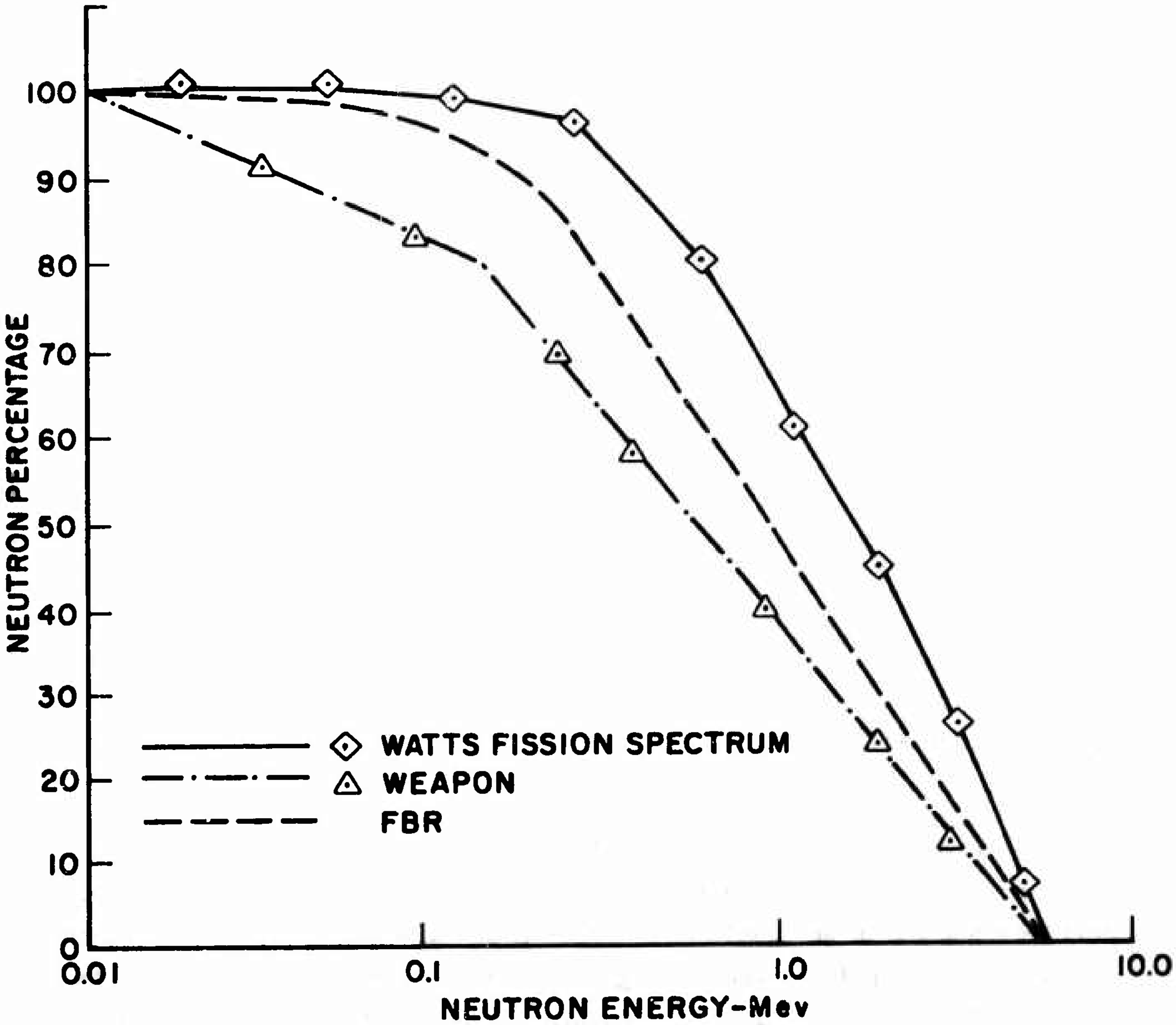

Figure 1. Comparison of Fission Spectra.

a. Recording Instruments

A dual recording system was used to ensure data recovery in case of a partial malfunction. An Ampex AR200 magnetic tape recorder was used as the primary system with a Honeywell 1508 visicorder as backup. The tape recorder was run in an FM record mode at 7.5 ips. A 2,500 cps bandwidth is obtained. The visicorder was run at 20 ips and used fluid damped galvanometers having a 5,000 cps response. The detector output was measured on a VTVM before and after each burst, as was the thermocouple output.

Data outputs for all the bursts were monitored through 250 feet of RG58 coaxial cable from the reactor cell.

SECTION III

TEST RESULTS AND ANALYSIS

The results of the burst series have been reproduced from the magnetic tape data and are presented in figures 2 through 7. In each case, the time of burst is indicated by the large peak in detector output. The smaller periodic peaks are due to the flashing light used as a standard source in all bursts.

The recovery time of the detector from the initial pulse is evident along with the longer recovery time to normal output operation. In all cases, the pulse recovery time was on the order of 100 times the FBR pulse width. Approximately 100-150 milliseconds was required for the detector to resume normal amplitude outputs.

Figure 8 shows the gamma dose and neutron flux received for each of the six bursts. On two of the bursts (operation number 948 and 951) a measure of gamma dose was not obtained.

Figure 9 is a composite plot showing detector calibration before and after the test series. The closeness of the two curves indicates that the detector experienced very little permanent damage if any.

Table 2 is a listing of pertinent detector characteristics before and after the burst series.

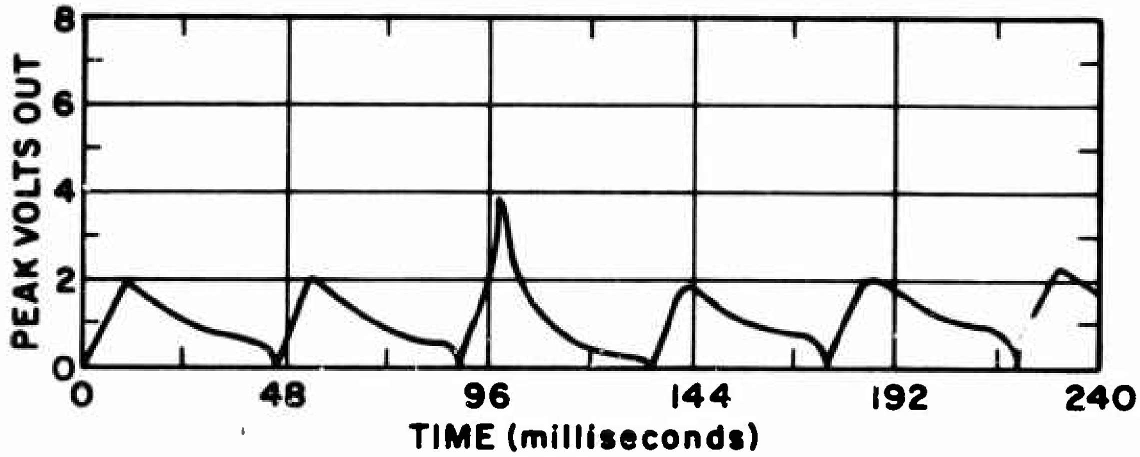

Figure 2. Burst 1, Operation Number 951.

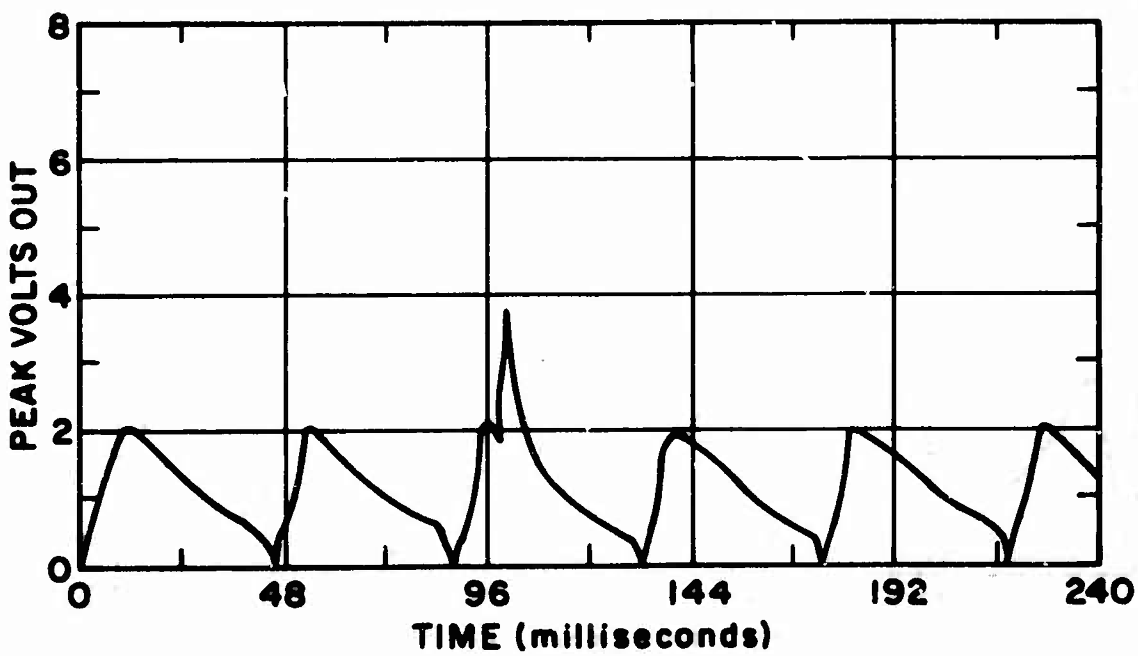

Figure 3. Burst 2, Operation Number 946.

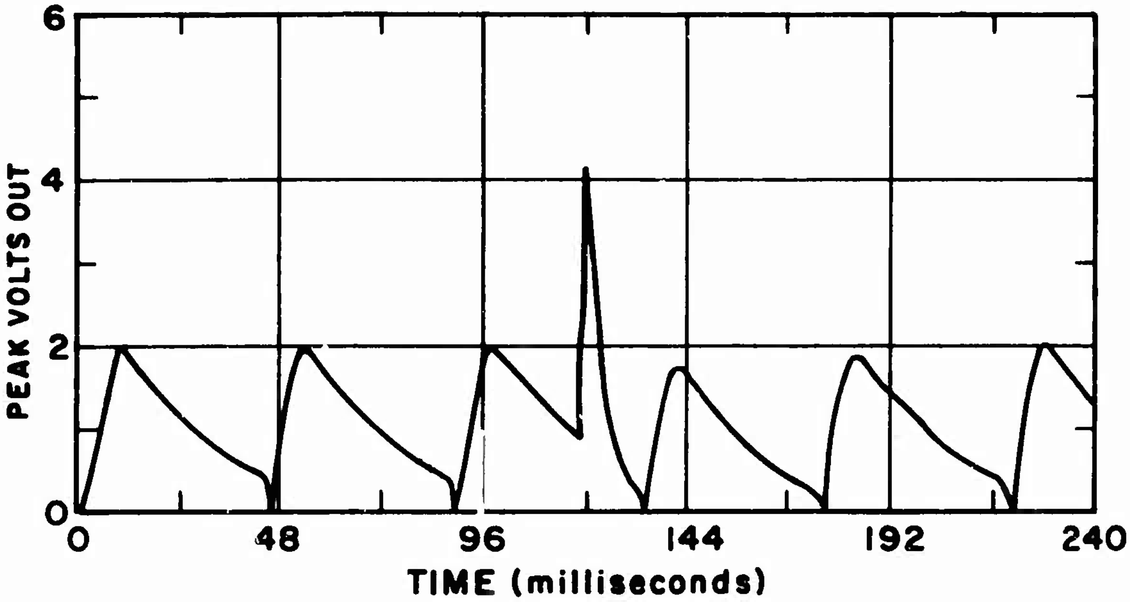

Figure 4. Burst 3, Operati[illegible] Number 947.

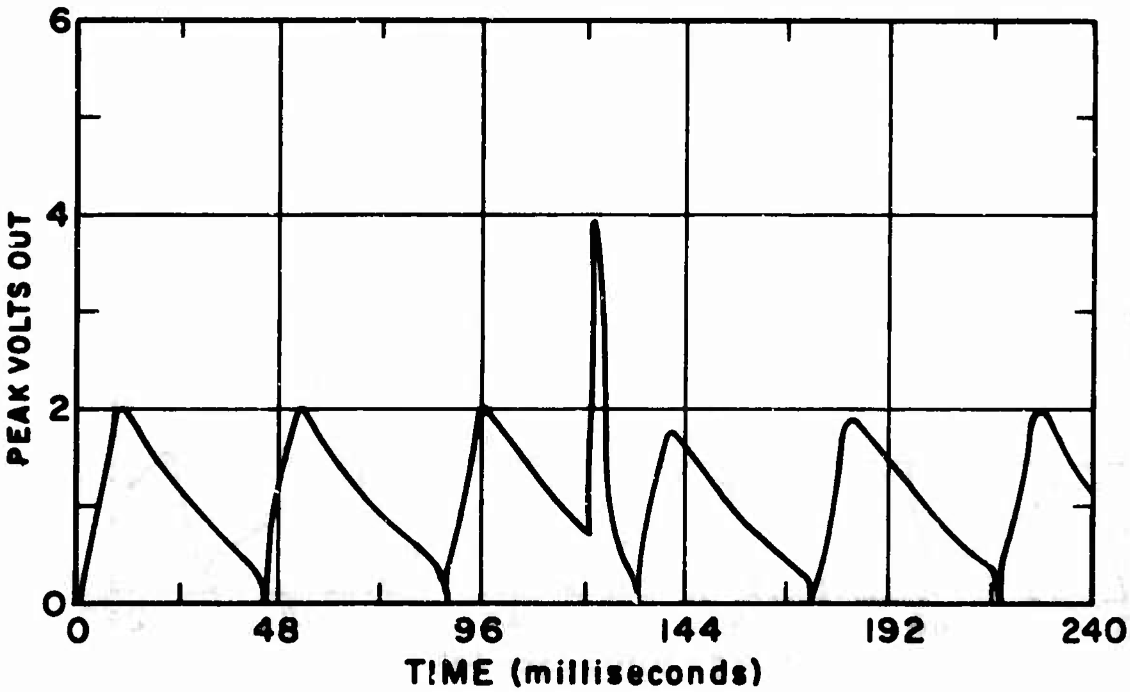

Figure 5. Burst 4, Operation Number 948.

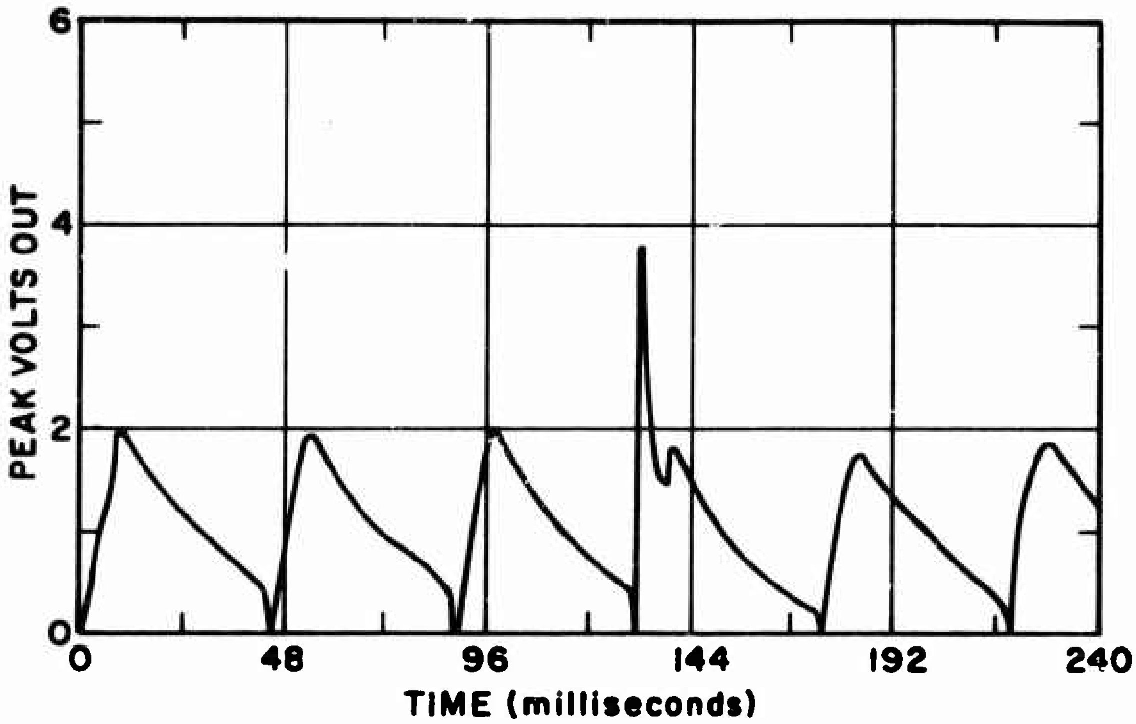

Figure 6. Burst 5, Operation Number 949.

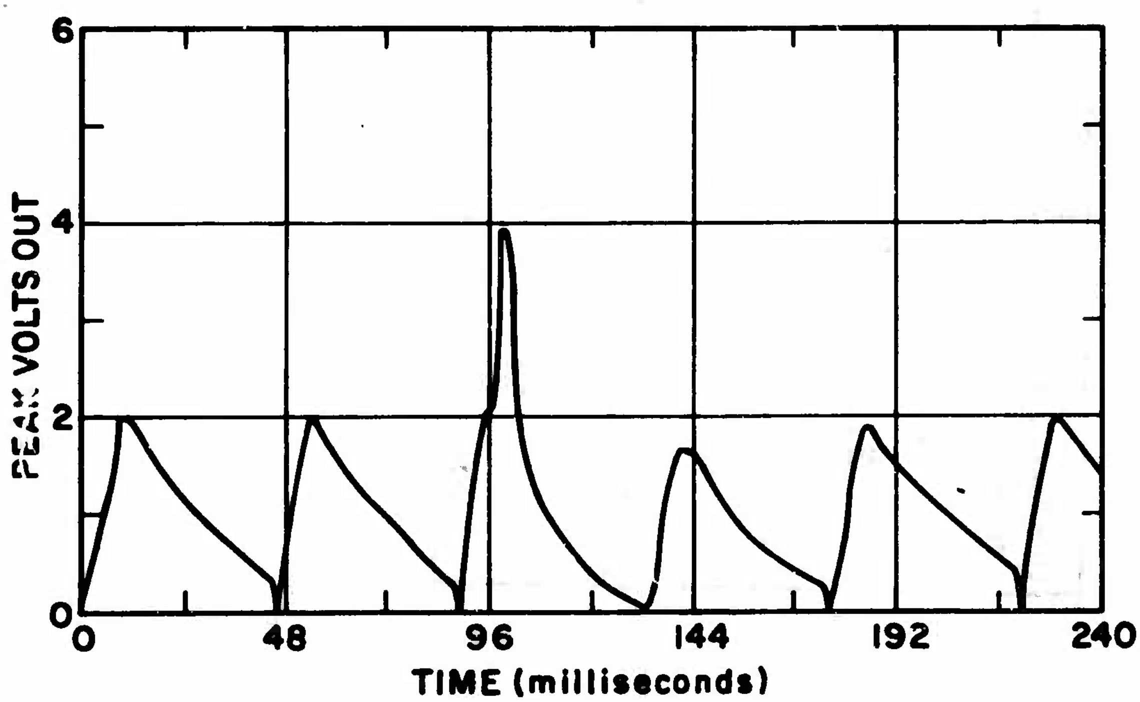

Figure 7. Burst 6, Operation Number 950.

OPERATION NUMBER	DISTANCE OF DETECTOR FM CORE (feet)	ΔT#(°C)	FLUX NEUTRONS cm^2 > 3.0 Mev	TOTAL INTEGRATED DOSE NEUTRONS/cm^2	GAMMA DOSE RADS (H_2O)
946	5	208	3.52×10^{10}	2.58×10^{11}	112
947	1.5	22C	2.29×10^{11}	1.68×10^{12}	470
948	1.5	221	2.29×10^{11}	1.68×10^{12}	–
949	1.5	158	2.89×10^{12}	2.12×10^{13}	573
950	1.5	188	3.76×10^{11}	2.76×10^{12}	720
951	1.5	201	3.871×10^{11}	2.84×10^{12}	–

Figure 8. Characteristics of Test Bursts.

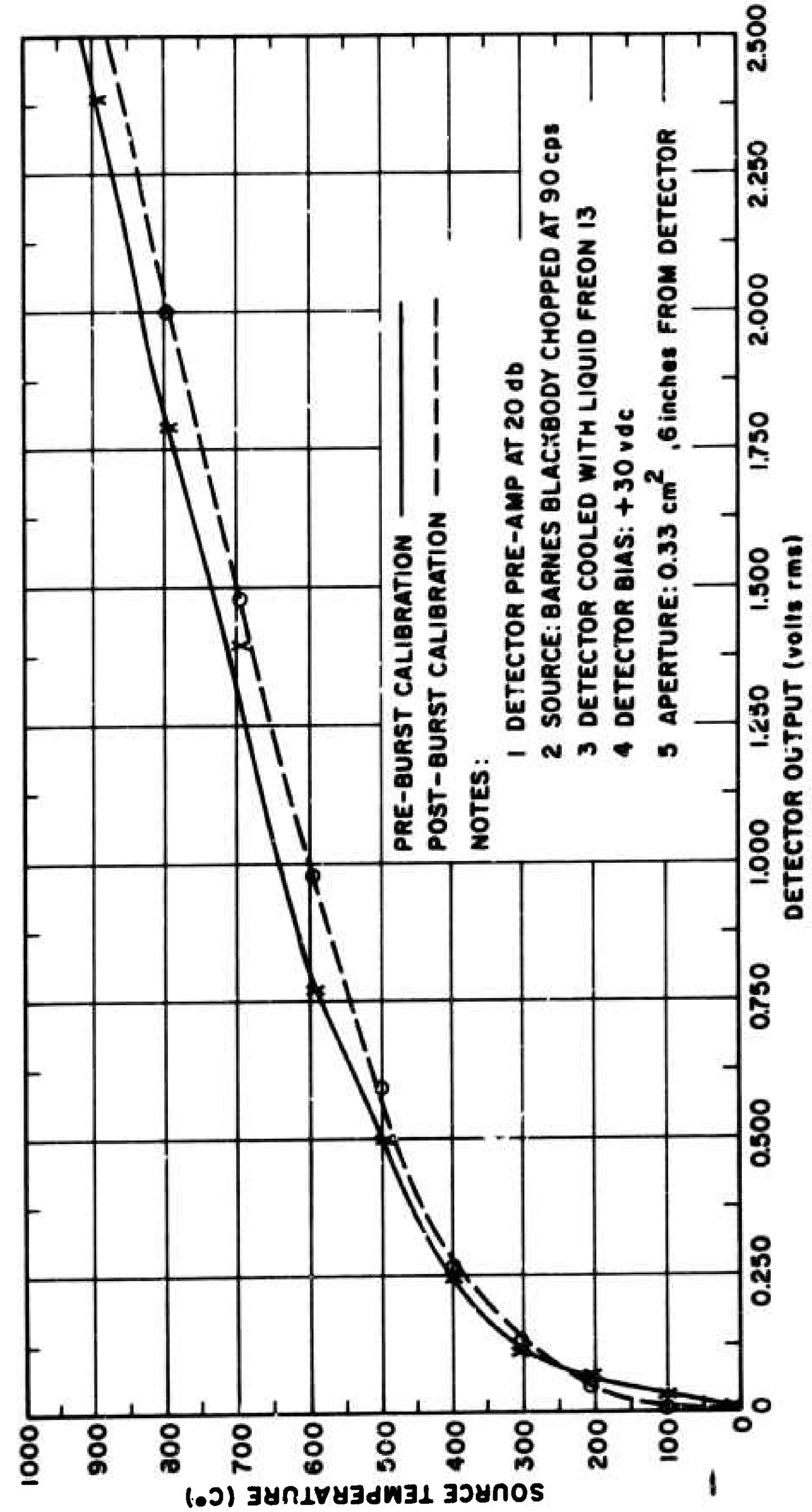

Figure 9. Pre- and Post-Burst Detector Calibration.

Table II

PRE- AND POST-BURST DETECTOR CHARACTERISTICS

Parameter	Before Burst Series	After Burst Series
Warm Resistance	350K ohms	400K ohms
Cold Resistance	5 Meg ohms	9 Meg ohms
Warm Noise	50 μvolts	80 μvolts

NOTE: Parameters were measured with a one-megohm load and +30 volts DC detector bias.

SECTION IV

CONCLUSIONS

The results of this test series indicate that a lead selenide detector exhibits a high degree of radiation hardness. The rapid recovery from the simulated nuclear burst is encouraging. Even more so is the apparent small degree of permanent damage as a result of a test series that totals a substantial integrated neutron flux. The small difference in the detector calibration curves could be due to experimental variations.

The largest effect of the radiation exposure appears to be in changes of detector resistance and an increase in detector noise. This would result in effectively making the detector less sensitive to small signals.

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